CALCIUM AND PHOSPHORUS REQUIREMENTS FOR DEVELOPING BOARS

by

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INTRODUCTION

Maintaining breeding schedules is generally recognized as the most important management problem in confinement pork production. Although female deficiencies, such as failure to exhibit estrus and shortened estrus, have been identified as major problems in confinement breeding, the inability of boars to perform satisfactorily under confinement conditions has contributed to lower reproductive performance. Both purebred and commercial producers have reported an increasing number of leg problems in developing boars. The requirement of calcium and phosphorus for growing and developing boars has not been completely resolved.

The National Research Council (1973) lists the calcium and phosphorus requirements of young boars as 0.75% and 0.50%. The definition of a young boar (as applied to the above requirements) is a boar weighing from 110 to 180 kg, or for boars near serviceable size and age. Application of the Ca and P requirements of growing and finishing pigs is questionable since boars are trimmer and usually grow at a faster rate.

Data from several reports (Chapman et al., 1962; Combs et al., 1962; Cromwell et al., 1972; Libal et al., 1969; Miller et al., 1964; Rutledge, Hanson and Meade, 1961; Zimmerman et al., 1963; Stockland and Blaylock, 1973; Tanksley, 1975; Bayley et al., 1975; Fammatre et al., 1977) have suggested that the calcium and phosphorus requirements for optimum skeletal

development are greater than the requirements for maximum gain and feed efficiency of swine.

The objective of this experiment was to determine the dietary levels of calcium and phosphorus needed by rapidly growing boars (29 to 118 kg) to provide optimum growth performance and maximum bone development.

REVIEW OF LITERATURE

Researchers have studied the calcium and phosphorus needs of growing and finishing of swine for many years. Those studies have shown that several factors have an influence on the calcium and phosphorus needs of the pig. Some factors which can influence the requirement are: criteria used to determine calcium and phosphorus adequacy, the method of processing the diet, ratio of calcium to phosphorus in the diet, other elements in the diet and environmental factors.

There has been little published concerning the calcium and phosphorus needs of growing and developing boars.

Calcium and Phosphorus Requirement

The National Research Council (1968) listed the calcium requirements of growing swine from 10 to 35 kg as 0.65%. The requirement for phosphorus for the 10 to 35 kg growing pig was listed as 0.50%. Doige et al. (1975) reported that the levels of calcium and phosphorus for normal skeletal development as measured by bone weight recommended by NRC was adequate.

Aubel et al. (1936) suggested that the minimum requirements of phosphorus in the ration of growing pigs was between 0.27 and 0.30%.

Combs et al. (1962) used pigs weaned at 2 weeks of age to determine the effects of dietary phosphorus level on weight gain, feed efficiency, percent ash and radiographs of the fibula and femur along with length of femur. Upon evaluation

of all criteria they reported that the phosphorus requirement of pigs from 2 to 7 weeks of age was 0.44% of the ration and that with this phosphorus level the optimum Ca:Phos ratio was 0.9:1.

Combs et al. (1962) investigated different sources and levels of calcium for pigs weaned at 2 weeks of age until 6 weeks of age. They reported that the most efficient utilization of feed occurred at 0.40% and 0.52% ration calcium when dietary phosphorus was held constant at 0.44%. They concluded that neither rate or efficiency of gain were significantly influenced by the sources of calcium, ground limestone, oyster shell or gypsum used in their study.

Rutledge et al. (1961) suggested that 0.8% dietary calcium is near the minimum required for normal bone development in pigs between 3 and 9 weeks of age when the dietary phosphorus level was held constant at 0.6%.

Coalson et al. (1972) observed maximum gain, feed conversion, and skeletal development during the growing period from the third to ninth week in pigs fed 0.95% dietary calcium in a semi-purified diet. The pigs were reared in incubators until 2 weeks of age, then placed in environmentally controlled rooms thru the ninth week. Coalson et al. (1974) reported similar results to those obtained by Coalson et al. (1972).

Chapman et al. (1962) studied the calcium and phosphorus requirements of growing-finishing swine using a 6 x 7 factorial design, with dietary levels of calcium and phosphorus ranging from 0.2% through 0.8% and 0.2% through 0.7%, respectively. They reported that the dietary requirements to assure maximum

rate of gain and optimum skeletal development appeared to be 0.8% calcium and 0.6% phosphorus, for the pigs from 25 to 100 lbs, and 0.7% calcium and 0.5% phosphorus from 100 to 200 lbs, on a yellow corn-soybean basal diet.

Cromwell et al. (1970) used 344 SPF - Yorkshire pigs to determine the effects of dietary phosphorus and calcium level in corn-soybean meal diets on rate and efficiency of gain, carcass characteristics, and bone mineralization for growing and finishing swine from 18 to 96 kg body weight. They concluded that feeding less than 0.5% and 0.4% phosphorus during the growing and finishing periods respectively resulted in significantly slower and less efficient gains and carcasses with more backfat and lower ham-loin yield. This result agreed with that reported by the same groups two years later (1972). Neither rate or efficiency of gain, nor phosphorus content of the turbinates and metacarps was improved when dietary phosphorus was greater than 0.5% and 0.4% during the growing and finishing periods, respectively.

Stockland and Blaylock (1973) studied the calcium and phosphorus requirement for growing and finishing pigs by using limestone and phosphoric acid as Ca, P supplements, respectively. A calcium level of 0.3% of the diet provided maximum gain and feed efficiency. The level of dietary calcium required to maximize skeletal development was 0.6% of the diet. The phosphorus requirement of swine from 27 to 91 kg was 0.45% or less for maximum gain and feed efficiency as well as for maximum skeletal development. Lameness tended to be slightly greater in pigs fed diets containing 0.45% phosphorus compared to pigs

fed the diets containing 0.65% phosphorus. Dietary calcium levels did not influence the incidence of lameness in this study.

The National Research Council (1973) recommended the calcium and phosphorus requirements for growing and finishing swine as 0.5% and 0.4%, respectively. Pond et al. (1975) showed that the NRC recommended calcium and phosphorus requirement (1973) for growing-finishing swine did maintain normal growth and feed efficiency, but bone ash tended to be higher from pigs fed a level of 1.2% calcium and 1.0% phosphorus.

Libal et al. (1969) studied levels of calcium and phosphorus using 190 Yorkshire X Hampshire cross-bred pigs. Criteria used to determine calcium and phosphorus adequacy was: weight gain, feed intake, feed conversion, bone weight, bone breaking strength (BKS), percent bone ash and incidence of Atrophic Rhinitis (AR) in growing and finishing pigs. Levels of the two elements did affect bone formation as shown by BKS and bone weight data. Increasing phosphorus in equal increments from 0.3% to 0.7% of the diet improved average daily gain in a linear manner. The linear effect of dietary phosphorus levels on feed intake was significant ($P<.005$) with the highest intake occurring at the 0.6% level. Also, the linear effect of phosphorus on BKS approached significance. Bone breaking strength and bone weight data were also significantly ($P<.005$) higher in pigs fed diets with 0.65% calcium than for those fed 0.35%. BKS and bone weight had a correlation of 0.82% in this experiment. The results of these experiments showed that calcium and phosphorus levels could vary

considerably without significantly affecting daily gain and feed conversion of pigs.

Newman et al. (1976) reported that growing pigs (16 to 46 kg) fed 0.6% and 0.8% phosphorus gained faster ($P<0.5$) than pigs fed 0.4% phosphorus during the finishing period (46 to 101 kg) when fed barley-soybean meal diets. This level was higher than that suggested by the NRC requirement (1973).

Bayley and Thomson (1969) evaluated the effect of feeding corn-soybean diets containing 0.9% calcium and one of the following levels of phosphorus, 0.34%, 0.44%, 0.50% or 0.56% in the form of meal or as pellets using gain and bone development as criteria. Gain and bone development were improved by phosphate addition to provide 0.5% phosphorus in the diet, but increasing levels beyond this caused no further response in growing pigs.

Plumlee et al. (1958) reported that adding 0.15% phosphorus from either dicalcium phosphate or phosphoric acid to a practical corn-soybean oil meal ration (0.30% phosphorus) resulted in a highly significant increase in rate of gain, serum phosphorus values and also a marked improvement in feed efficiency.

Allee et al. (1976) used ninety pigs to determine the minimal level of supplemental phosphorus required by growing-finishing pigs. Graded levels of supplemental phosphorus (0, 0.05, 0.10, 0.15 and 0.20% of the diet) from dicalcium phosphate were added to a 16% protein milo-soybean meal basal diet containing 0.36% phosphorus. The results of their experiment suggested that growing-finishing pigs should be supplied at

least 0.15% supplemental inorganic phosphorus for maximum daily gain and feed efficiency.

Peo et al. (1969) used one hundred and twenty-six Hampshire X Yorkshire crossbred pigs to determine the effects of calcium and phosphorus on growth, feed efficiency, feed intake, bone characteristics and incidence of atrophic rhinitis in growing-finishing swine. The treatment levels of total phosphorus (0.30%, 0.50% and 0.70%) were used with three levels of calcium (0.35%, 0.65%, 0.95%) in a 3 x 3 factorial design. The results showed that calcium and phosphorus had a significant linear effect on daily gain with the quadratic effect also being significant for phosphorus. No significant differences were found for feed intake or feed conversion. Metatarsal bone weight was significantly increased as the level of calcium and phosphorus in the diet increased. Calcium and phosphorus significantly affected breaking strength in a manner similar to metatarsal bone weight.

Fammatre et al. (1977) used a factorial experiment in a randomized complete block design to evaluate the effects of two levels of dietary calcium : phosphorus (0.90/0.70% or 0.65/0.50%, respectively) in an 18% protein corn-soybean meal diet for growing swine (19 to 52 kg). Animals were then continued to market weight being fed one of two levels of calcium : phosphorus (0.65/0.50% or 0.50/0.405, respectively) each at two protein levels (13 or 16%). During the growing period both gain and feed intakes increased ($P<.01$) when the higher calcium : phosphorus level was fed. Bone ash content of the sixth rib, femur, metacarpal and proximal phalanx increased significantly

at the higher mineral level. However, during the finishing period there were no residual effects from the previous growing treatments on gains or feed intake responses. Finisher protein or mineral levels had no effect on performance criteria. Although there was an increased bone ash content from those pigs fed the higher mineral diet at 52 kg, differences were not apparent at 92 kg from any of the treatment variables. Performance for the combined growing-finishing period was not affected by any of the dietary treatments imposed on the pigs.

Tanksley (1975) individually fed thirty-six crossbred male pigs a milo soybean meal diet to determine the effect of calcium and phosphorus levels on rapidly growing boars. Graded levels of calcium and phosphorus were fed from 25 kg to 95 kg. Two calcium to phosphorus (Ca:P) ratios; 1:1 and 1.2:1, were used at three phosphorus levels, 0.50%, 0.75% and 1.00%. Feed intake, daily gain, feed efficiency, femur and metacarpal, ash, strength, elasticity, weight, length, sidewall thickness, sidewall area and outside diameter were used as criteria for adequacy. Based on the criteria evaluated, they concluded that a level of 0.50% and 0.50% calcium and phosphorus, respectively was adequate for optimum gain and feed efficiency. However, maximum bone development occurred at 1.20, 1.00% (Ca, P) for the femur and 0.75, 0.75% (Ca, P) for the metacarpals. These levels are higher than the NRC (1973) requirements for growing-finishing swine.

Liptrap et al. (1971) used 36 boars and 36 gilts in two experiments to study the calcium requirement of developing boars and gilts. The diets were formulated using a corn-soybean

meal ration containing 0.50% phosphorus and one of the following levels of calcium; 0.60%, 0.90%, 1.20%. Boars were more efficient in feed conversion, but feed consumption was not different. Bone ash and calcium concentrations were higher for gilts than the boars, and increased dietary calcium tended to increase bone calcium concentrations. Boars had heavier and stronger bones than the gilts. Bone breaking strength and bending moment were reduced by increased dietary calcium. Some of the parameters investigated indicated that the available dietary phosphorus was limiting the expression of any higher requirement for calcium. They reported that under the conditions of these experiments, the calcium requirement of developing boars and gilts was not greater than 0.6% of the diet.

Bayley et al. (1975) evaluated the effect of feeding corn-soybean meal diets to growing and developing boars and gilts from 25 to 90 kg. They reported that when the dietary calcium level was held constant at 0.90% and the phosphorus level increased from 0.32% to 0.40% of the diet, growth of boars increased significantly, ($P<.05$) but bone development responded to all three increments of phosphorus 0.36%, 0.40% and 0.44%, respectively. Also when the dietary level of calcium and phosphorus was formulated at 0.80% and 0.40%, respectively and phosphorus levels were raised to 0.6%, 0.8% and 1.0%, the increased level of phosphorus from 0.40% to 0.60% improved the gain of boars significantly ($P<.01$). The force required to break the femurs responded the same way. The results of these experiments indicated that the dietary level supporting

maximum growth of boars from 25 to 90 kg. was between 0.40% and 0.60% dietary phosphorus. However, for maximum bone development more than 0.60% phosphorus was required.

Ca, P and Atrophic Rhinitis

Cromwell et al. (1970, 1972), Libal et al. (1969), Lindley (1967), Liptrap et al. (1970) and Peo et al. (1969), did not report any benefit to feeding high levels of calcium and phosphorus to prevent excessive resorption of the osseous frame of the turbinate bone. Brown, Krook and Pond (1966) reported that high levels of calcium and phosphorus were required to prevent this problem. They all agreed that the turbinate bones were more sensitive to phosphorus and calcium deficiencies than other skeletal tissues.

Sources of Phosphorus

Many supplements are being used as sources of phosphorus for swine. Most reports are concerned with corn-soybean meal type diets supplemented with dicalcium phosphate and limestone as the primary source of phosphorus and calcium, respectively.

Miller et al. (1953), Chamberlin et al. (1963) reported that the phosphorus from dicalcium phosphate, Curoca Island phosphate, bone meal, and defluorinated phosphate were all good sources of readily available inorganic phosphate. Newman et al. (1976) reported that defluorinated rock phosphorus appeared to be equal to sodium salt of phosphate and dicalcium phosphate as a source of supplemental phosphorus for growing and finishing pigs fed barley-soybean meal diets using rate and efficiency of gain as criteria for comparison.

Plumlee et al. (1958) studied the utilization of phosphorus supplements by swine. Dicalcium phosphate, monocalcium phosphate, and phosphoric acid were found to be equal. These were followed in order named by steamed bone meal, defluorinated phosphate, Curoca Island phosphate and soft phosphate with collodal clay.

Harmon et al. (1968) found that dicalcium phosphate supported more rapid gains than soft phosphate at a level of 0.5% dietary phosphorus, although rib and turbinate ash values were similar.

Soft phosphate with collodal clay has been found poorly available to farm animals and poultry. Such results were reported for cattle by Long et al. (1976), Plumlee et al. (1958) and Van Zante et al. (1967); for the chick by Grau and Zweigart (1953), Johnson and Phillips (1956), Miller and Joukovsky (1953) and Motzok and Branion (1956); for the turkey by Wilcox et al. (1954).

At the turn of the century, it was thought that only organic forms of phosphorus could be assimulated by the body and used for synthesis of phosphorus containing compounds in body tissue.

Chapman et al. (1955) suggested that growing-finishing swine did not utilize plant phosphorus as efficiently as inorganic phosphorus, as evidenced by a significantly poorer feed efficiency and average daily intake.

Moore and Tyler (1955) studied the utilization of phytin phosphorus in the digestive tract of the pig and found that it

was utilized to a greater extent when diets contained dicalcium phosphate. Woodman and Evans (1948) showed that pigs 50 to 90 kg in weight absorbed 30 to 40% of the phosphorus in a barley-wheat bran diet with no added inorganic phosphorus.

Noland et al. (1968) used growing swine to evaluate the availability of the phosphorus in a corn-soybean meal basal diet. Diets were formulated assuming availabilities of either 30, 40, 50 or 60%. No significant differences in rate or efficiency of gain were obtained in this trial either to 45 kg or 90 kg. The results suggested that the phosphorus in a corn-soybean meal diet was 30 to 60% available for growing swine.

Bayley and Thomson (1969) indicated that only 20-30% of the phosphorus in corn and soybean meal can be utilized by the pig.

Tonroy et al. (1970) used corn grit phosphorus as a control to evaluate the availability of phosphorus in sorghum grain. They reported that the phosphorus retention values were 4.49% and 1.86% for the 0.3% and 0.5% phosphorus levels, respectively.

Feed Processing and P

It is apparent that some methods of feed processing can effect the availability of phytin phosphorus.

Hart et al. (1909) observed that soaking wheat bran overnight allowed the enzyme phytase to act with the result that some of the phytin phosphorus in bran was hydrolyzed to inositol and inorganic phosphorus.

McCance and Widdowson (1944) demonstrated that wet heat quickly destroyed phytase, but dry heat did not. The increase in inorganic or available phosphorus might be due to the hydrolysis of phytin instead of the enzyme reaction.

Summers et al. (1967) reported that steam-pelleting appeared to render more than 25% of the remaining phosphorus available to the chick when using wheat in the basal diet. Pelleting wheat without sufficient steam did not seem to have the same effect.

Bayley et al. (1969) demonstrated that phosphorus absorption from a diet containing no added phosphorus (0.35% P, 0.90% Ca) was increased from 19 to 29% by steam pelleting, but steam pelleting did not have this effect on the diet containing the highest level (0.56% P, 0.90% Ca) of phorphorus. The increased absorbability of the phosphorus in the low-phosphorus diet as a result of steam pelleting was evidenced in greater gains and improved bone development. Steam pelleting the diets with adequate phosphorus improved gain and feed efficiency, but this effect could not be explained on the basis of either increased phosphorus availability or increased digestibility of the energy or nitrogen in the diet.

Calcium : Phosphorus Ratio

The ratio of calcium to phosphorus is a factor in growth and bone formation of the pig. In general, best results have been obtained with a calcium-phosphorus ratio between 1.0 and 2.0. When the proportion of calcium to phosphorus was greater than 3.0, the pigs became more rachitic and the requirements

for vitamin D were increased. Evidence obtained indicated that the phosphorus content of the ration should not be less than approximately 0.60% for good growth and bone formation in the absence of added vitamin D (Bethke et al. 1933).

Optimum ratio of calcium to phosphorus will vary depending on the weight and age of the pig and the level of calcium and phosphorus in the diet. If the phosphorus level is barely adequate, for example, and calcium intake is high, the excess calcium may interfere with phosphorus absorption from the intestinal tract, resulting in loss in the feces. Thus, the Ca:P ratio affects efficiency of utilization of phosphorus.

Lloyd et al. (1961) reported that increasing the dietary calcium level from 1.2 to 4.0% in the rations of early weaned pigs significantly decreased average daily gain and the apparent digestibility of total carbohydrate, but had no other adverse effects when the dietary phosphorus level was held constant at 1.0%.

Chapman et al. (1962) found the calcium-phosphorus ratio was more important when minimal dietary levels of phosphorus were fed. These results agreed with those of Cromwell et al. (1970).

Vipperman et al. (1974) used 27 Hampshire Yorkshire cross-bred barrows in three metabolism trials to determine the effects of dietary calcium and phosphorus level upon calcium, phosphorus and nitrogen balance in growing swine. Calcium to phosphorus ratios were not as important in the utilization of these two elements as dietary levels per se. The optimum calcium to

phosphorus ratio varied with the level of calcium and with the level of phosphorus in the diet. The utilization of calcium appeared to be less affected by calcium to phosphorus ratios than is the case with phosphorus utilization.

Doige et al. (1975) used a factorial design with three levels of calcium and three levels of phosphorus to study calcium and phosphorus deficiencies and imbalances in swine fed from 22 kg to 90 kg. Extreme Ca:P ratios in the diet impaired both performance and skeletal development. All changes were minimal if low levels of either element were accompanied by a Ca:P ratio near 1.25:1. Low calcium-high phosphorus rations resulted in parathyroid enlargement, reduced bone mass, increased numbers of osteoclasts and fibrous replacement of bone. In animals fed high calcium-low phosphorus rations, hypophosphatemia, reduced bone ash and overgrowth of epiphyseal plates were observed.

The exactness of the calcium : phosphorus ratio is less emphasized now than it was in early research work. The most favorable appears to be between 1:1 and 1.5:1. In the NRC, the ratio will average about 1.3:1 with all weights of growing and finishing swine, while the average recommended calcium:phosphorus ratio for breeding swine is 1.5:1 (Giesler, 1974).

Vitamin D and Ca, P

Harris and Innes (1931) postulated that vitamin D increased the net absorption of calcium and phosphorus, but some of the work done since then has indicated that its action is on calcium absorption only.

Nicolaysen et al. (1953), Keane et al. (1956) demonstrated that the primary function of vitamin D is to promote calcium absorption from the gut. This report is supported by work done by Harrison and Harrison (1961), Ramussen and DeLuca (1963).

Those studies indicate that vitamin D does have an effect on phosphorus absorption but it is secondary to the calcium absorption and that apparently the regulation of phosphate absorption of vitamin D is indirectly through calcium absorption.

Boutwell et al. (1946), Krieger et al. (1941) and Spitzer et al. (1948) all demonstrated that in the absence of vitamin D, phytic acid phosphorus was not available to the rat, but when vitamin D was fed, more of the phosphorus was utilized. In studies with chicks, McGinnis et al. (1944) showed that phytin phosphorus was poorly available in the absence of vitamin D, but that it was nearly as available as inorganic phosphorus when adequate vitamin D was fed.

Those studies suggested that the phytin phosphorus was made available by the action of an intestinal enzyme, phytase, capable of splitting the phytin molecule. It appeared that vitamin D might be necessary either for phytase formation or for its proper function. A report by Spitzer et al. (1948) suggested that the phytase content of the small intestine of rats fed phytin phosphorus and vitamin D showed no difference in phytase concentration. They suggested that the vitamin D function was for a secondary effect on phytase, not in phytase formation.

DeLuca (1974) proposed that the most active form of vitamin D was 1,25-$(OH)_2$-D_3. Under conditions of hypocalcemia, the parathyroid glands are stimulated to secrete parathyroid hormone, which in turn stimulates synthesis of the 1,25-$(OH)_2$-D_3. The 1,25-$(OH)_2$-D_3 together with the parathyroid hormone functions to mobilize calcium from previously formed bone. Thus, the 1,25-$(OH)_2$-D_3 must be regarded as a calcium mobilizing hormone. He also found that the 1,25-$(OH)_2$-D_3 acted independently of its Ca transport function to stimulate the elevation of serum inorganic phosphate levels.

EXPERIMENTAL PROCEDURE

General Introduction

Forty-two crossbred boars (¼D, ¼Y, ½H) averaging 29 kg were randomly assigned by weight and litter to seven dietary treatments. (A) 0.55% calcium, 0.45% phosphorus; (B) 0.74% calcium, 0.60% phosphorus; (C) 0.93% calcium, 0.75% phosphorus; (D) 1.1% calcium, 0.90% phosphorus; (E) 1.30% calcium, 1.05% phosphorus; (F) ration B to 150 lbs (68.1 kg) followed by ration D to 260 lbs (118.0 kg); (G) ration D to 150 lbs (68.1 kg) followed by ration B to 260 lbs (118.0 kg). Dicalcium phosphate was added to a corn-soybean meal diet containing 0.32% phosphorus at the expense of the corn to give a total phosphorus level of 0.45%, 0.60%, 0.75%, 0.90%, 1.05% as listed in the 5 dietary treatment levels (A through E) above. Limestone was used to provide 1.2:1 ratio of calcium to phosphorus in all dietary treatments. Composition of the diets is shown in Table 1 and a calculated analysis of each diet is provided in Table 2.

Boars were fed a corn-soybean meal ration containing 18% protein, 0.80% Ca and 0.60% P from weaning until initiation of the trial. This ration met all the nutrient requirements recommended by NRC (1973).

Boars were housed in an open-fronted barn, two per pen (1.2 m X 4.9 m). Pigs in each pen had access to a one-hole self feeder and an automatic waterer. The experimental diets

TABLE 1. COMPOSITION OF DIETS[a] FED

Calculated:	A	B	C	D	E
Calcium, %	.55	.74	.93	1.10	1.30
Phosphorus, %	.45	.60	.75	.90	1.05
Ingredients, %					
Corn	73.24	72.37	71.50	70.63	69.75
Soybean meal[b]	24.00	24.00	24.00	24.00	24.00
Dicalcium phosphate[c]	0.62	1.33	2.05	2.76	3.50
Limestone[d]	0.79	0.95	1.10	1.26	1.40
Salt	0.50	0.50	0.50	0.50	0.50
Vitamin premix[e]	0.50	0.50	0.50	0.50	0.50
Trace mineral[f]	0.10	0.10	0.10	0.10	0.10
Antibiotic premix[g]	0.10	0.10	0.10	0.10	0.10

[a]Diets fed in meal form.

[b]Soybean meal used analyzed 0.53% calcium, 0.55% phosphorus.

[c]Dicalcium phosphate: 21% P, 18% Ca.

[d]Limestone contained 33% calcium.

[e]Amounts per kg: 881057 USP units of vitamin A, 66079 USP units of vitamin D_3, 991 mgs. of riboflavin, 2643 mgs. of d-pantothenic acid, 66.05 mgs. of choline, 5506.6 mgs. of niacin, 4405 I.U. of vitamin E, 4.84 mgs. of vitamin B_{12}, 550 mgs. of vitamin K, 6.3 mgs. of antioxidant.

[f]Containing 5.5% manganese, 10% iron, 1.1% copper, 10% zinc, 0.15% iodine, 0.1 cobalt.

[g]ASP-250 until boars reached 90 kg, then tylan 10 from 90 kg to 118 kg.

TABLE 2. ANALYSIS OF DIETS FED

Item:	%				
Dietary Ca	0.55	0.74	0.93	1.10	1.30
Dietary P	0.45	0.60	0.75	0.90	1.05
Calculated					
Crude protein	17.15	17.07	16.99	16.92	16.84
Lysine	0.85	0.85	0.85	0.85	0.85
Analyzed					
Calcium	0.56	0.77	0.81	1.10	1.30
Phosphorus	0.55	0.63	0.68	0.88	1.27

were fed in meal form and the boars were weighed off trial by replicate as they reached approximately 118 kilograms. They were then slaughtered in the Animal Science and Industry Department meat laboratory, and their carcass backfat and length determined.

Bone Measurements and Analyses

Both front legs were removed from each boar at the elbow joint during slaughter. From these, the radius and ulna were obtained for experimental comparison. The soft tissue was removed and bones were then cooked for 6 minutes at 95 C and the remaining adhering tissue was manually removed. The radius and ulna were separated, placed in individual plastic bags, and stored in a freezer between each segment of the study.

Ulna breaking force and breaking strength was determined by means of a Riehle testing machine (Figure 1). Bones were placed on the supports in the manner shown in Figure 2. The machine was loaded at the slowest possible speed and the force required to break each bone was recorded. The supports were 2.5 cm in diameter and 10.1 cm apart. A third rod, 2.5 cm in diameter, was aligned with the center of the bone driven down by the press until the bone was broken (Figure 3). The force in kg required to break the bone was automatically recorded.

Breaking strength or "stress" was calculated as:

$$S \text{ (ksc, kg/cm}^2) = MC/I$$

$$= \frac{F\ (do/2)}{/64\ (do^4 - di^4)}$$

$$= \frac{F\ (64)\ do}{2\ (do^4 - di^4)}$$

$$= \frac{30\ F\ do}{(do^4 - di^4)}$$

where, M is moment

C is distance from the neutral axis to the point of maximum stress

F is force required to break the bone

I is inertia of moment

do is outside diameter of ulna at the breaking point

di is inside diameter of ulna at the breaking point.

Wall thickness was determined by using a cross-section of the ulna. Four ink stamps were made on each bone and 3 (those indicating only a natural bone cross-section without ink distortion) stamps were traced onto vellum paper. A compass and ruler was used to measure the length of the cross-section. The length was divided by 2 and the compass reset. Each bone stamp was marked on each side at half the distance of the total length of the cross-section in this manner. A line was drawn between these two points as shown in Figure 4. Wall thickness was then determined by an average of 6 measurements per bone (3 stamps, 2 sides per stamp). The inside diameter was determined by the average of 3 measurements per bone (3 stamps, 1 inside measurement per stamp). The outside diameter was determined by the average of 3 measurements per bone (3 stamps, 1 outside measurement per stamp). The ulnas were cross-sectioned as indicated in Figure 5 to facilitate consistency in obtaining measurements.

Both the radius and the ulna were halved, split with a meat saw and the bone marrow removed with hot water. The clean radius and ulna was used for ash, calcium and phosphorus determinations at the Animal Science and Industry Department analytical laboratory on a dry fat free basis. The phosphorus was analyzed by the method of Fiske and Subbarow (1925). In order to eliminate the P interference in Ca determination, the sample was diluted by adding SrCl before atomic absorption analysis.

Actual phosphorus and calcium determination was made by multiplying the % phosphorus and calcium obtained by the method of Fiske and Subbarow (1925) for phosphorus and by atomic absorption for calcium respectively by the dry fat free weight of each respective bone sample.

The analysis of variance, multiple range test and correlation were conducted according to the method outlined by Snedecor and Cochran (1971).

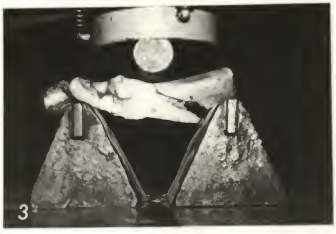
FIGURE 1. View of Richle FS20 testing used for bone breaking force and breaking strength determinations.

FIGURE 2. View of ulna in position for breaking.

FIGURE 3. View of ulna after breaking.

1

2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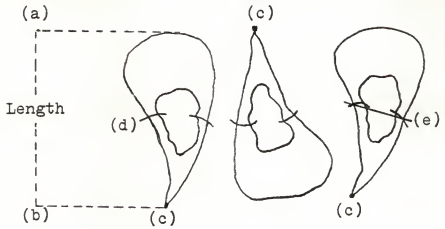

FIGURE 4. These three drawings represent actual cross-section stamps of the ulna. Length was measured from point (a) to point (b). A compass was set at half the length. Starting from point (c) on each stamp a mark was made on the sidewall of each stamp as depicted at point (d). Wall thickness was measured parallel to each compass mark as shown at (d). These six measurements (3 stamps, 2 sidewalls/stamp) were averaged to yield one wall thickness for each bone. A line was drawn from the point where the compass intersected the outside of the sidewall to the outside of the opposite sidewall as shown at (e). Inside diameter was measured along this line from the inside of each sidewall on all three stamps. These three measurements were averaged to give one average inside diameter per bone. Outside diameter was measured in the same manner as inside diameter but from the outside of each sidewall.

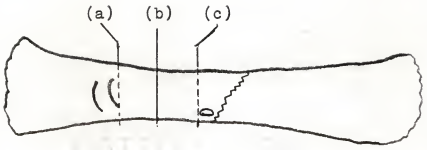

FIGURE 5. This drawing represents the method used for making a cross-section of each ulna after breaking force was determined. Figure 2 shows a picture of the bone. Point (a) represents the knob located directly over the support in Figure 2. Point (c) represents the blood vessel opening. These two points were used as guidelines in determining where to saw each bone. The distance from (a) to (c) was determined, then each bone was cross-sectioned at half the distance between the two points or at point (b).

RESULTS

The different levels of Ca and P did not significantly influence average daily gain, feed efficiency or average daily feed intake (Table 3). Similarly, there were no significant differences in carcass length or backfat thickness (Table 4).

Bone data is summarized in Tables 5, 6, 7, 8 and Figures 6 through 9. The weight required to break each bone (bone breaking force) of the right and left ulna increased ($P<.05$) linearly as dietary Ca and P levels increased (Tables 6 and 7). Maximum breaking force occurred at the highest level of dietary Ca and P (1.3% Ca, 1.05% P). Breaking force of the ulna (average of the left and right) increased linearly ($P<.05$) as Ca and P levels increased (Table 5). However breaking force was not significantly increased above a dietary treatment level of 0.93% Ca, 0.75% phosphorus (Figure 6). Apparently, higher levels of Ca and P are needed during the stage of growth from 68 to 118 kg since boars fed 0.74% Ca, 0.60% P from 30 to 68 kg followed by 1.1% Ca, 0.90% P from 68 to 118 kg produced bones similar in breaking force to those fed 0.93% Ca, 0.75% P (Tables 5, 6 and 7).

Bone breaking strength (obtained by placing the bone breaking force on a constant bone area basis) expressed as kg/cm^2, increased linearly ($P<.05$) as dietary Ca and P increased. Breaking strength was maximized at the highest level of dietary Ca and P (1.3% Ca, 1.05% P). However variation within treatments

prevented any significant separation in treatment means (Tables 5, 6 and 7).

Total ash content of the radius increased slightly, but not significantly in bones from boars fed higher levels of Ca and P (Table 8).

Ash content of the ulna increased ($P<.05$) linearly up to dietary levels of 0.93% Ca, 0.75% P. However the linear effect for treatments 0.93% Ca, 0.75% P through 1.30% Ca, 1.05% P was not significant (Figure 9).

No significant differences were found for the percentage of Ca or P in either the radius or ulna, although these values tended to increase slightly with increasing Ca and P levels. The Ca:P ratio of both the radius and ulna was about 2:1 (Tables 5, 6, 7 and 8).

Actual calcium (determined by multiplying the calcium % by the dry fat free weight of each bone sample) increased ($P<.05$) linearly with increasing Ca and P levels. Maximum actual calcium was observed at the highest level of Ca and P (Table 5). However, the linear effect was not significant for treatments 0.93% Ca, 0.75% P through 1.3% Ca, 1.05% P (Figure 8). The correlation ($r=0.83$) between breaking force and actual calcium content of the ulna indicated a strong positive relationship between these two criteria. Calcium deposition in the radius was not significantly influenced by treatment, however maximum calcium deposition occurred at 0.93% Ca, 0.75% P (Table 8).

Phosphorus content (obtained by multiplying the phosphorus % by the dry fat free weight of each bone sample) of the ulna

increased ($P<.05$) linearly with increasing levels of Ca and P. However, phosphorus deposition was maximized at 0.93% Ca, 0.75% P in both the radius and ulna (Tables 5 and 8, Figure 7).

Wall thickness of the ulna was not affected significantly by Ca and P levels (Table 5), although these values did increase slightly.

It appears that a level of 0.55, 0.45% dietary calcium and phosphorus, respectively, is adequate for growth of boars from 29 to 118 kg on a corn-soybean meal diet. However, for maximum bone development, a level of at least 0.93% Ca, 0.75% P should be supplied in the diets of rapidly growing boars.

TABLE 3. PERFORMANCE DATA ON BOARS FED INDICATED LEVELS OF CALCIUM AND PHOSPHORUS

Treatment	Dietary Ca %	Dietary P %	Daily gain[a] (kg)	Feed/gain[b]	Daily intake[b] (kg)
A	.55	.45	.89	2.97	2.65
B	.74	.60	.87	3.02	2.61
C	.93	.75	.94	2.91	2.73
D	1.10	.90	.83	3.09	2.55
E	1.30	1.05	.93	3.00	2.78
F	Trt B to 68 kg then D		.95	2.95	2.79
G	Trt D to 68 kg then B		.93	2.90	2.72
Standard Deviation			±.11	±.19	±.33

[a]Each value is the mean ± standard deviation of 6 boars.

[b]Each value is the mean ± standard deviation of 3 pens.

TABLE 4. CARCASS DATA FOR BOARS FED INDICATED LEVELS OF CALCIUM AND PHOSPHORUS

Treatment	Dietary		Slaughter[a] weight (kg)	Carcass[a]	
	Ca %	P %		Length (cm)	BF (cm)
A	.55	.45	121.7	83.6	2.36
B	.74	.60	118.4	82.5	2.14
C	.93	.75	124.2	84.4	2.49
D	1.10	.90	113.3	82.3	2.14
E	1.30	1.05	123.6	84.3	2.29
F	Trt B to 68 kg then D		125.2	84.1	2.52
G	Trt D to 68 kg then B		125.4	85.1	2.38
Standard Deviation[a]			±7.5	±2.1	±.28

[a]Each value is the mean ± standard deviation of six boars.

TABLE 5. BONE DATA ON THE RIGHT AND LEFT ULNA AVERAGED FOR BOARS FED INDICATED LEVELS OF CALCIUM AND PHOSPHORUS

Treatment	Dietary Ca %	Dietary P %	Ash[d] %	Ca[d] %	P[d] %	Actual Ca[d] gms	Actual P[d] gms	Breaking Force[d] kg	Breaking Strength[d] kg/cm^2	Wall Thickness[d] cm
A	.55	.45	63.2	24.2	12.3	11.0	5.6	290.0[a]	1531.7	.24
B	.74	.60	64.4	25.1	12.5	12.5	6.2	352.1[abc]	1893.6	.24
C	.93	.75	65.1	24.7	12.6	13.7	7.0	382.8[bc]	1900.6	.25
D	1.10	.90	64.8	25.7	12.6	12.9	6.5	370.3[bc]	2065.8	.23
E	1.30	1.05	65.4	26.0	12.6	14.2	6.9	414.3[c]	2329.4	.25
F	Trt B to 68 kg then D		65.7	25.0	12.6	13.2	6.6	380.6[bc]	2000.2	.25
G	Trt D to 68 kg then B		64.8	25.1	12.5	12.8	6.3	345.3[ab]	1877.2	.24
Standard Deviation[d]			±1.37	±1.18	±.35	±1.72	±.88	±53.3	±460.0	±.03

[abc]Means sharing a common superscript are not significantly different (P<.05).

[d]Each value is the mean ± standard deviation of six boars.

TABLE 6. BONE DATA LEFT ULNA FOR BOARS FED INDICATED LEVELS OF CALCIUM AND PHOSPHORUS

Treatment	Dietary Ca %	Dietary P %	Ash[c] %	Ca[c] %	P[c] %	Actual Ca[c] gms	Actual P[c] gms	Breaking Force[c] kg	Breaking Strength[c] kg/cm^2	Wall Thickness[c] cm
A	.55	.45	64.2	23.5	11.9	10.6[a]	5.4	262.6[a]	1443.7	.25
B	.74	.60	63.9	24.5	12.0	12.7[b]	6.3	340.7[b]	1787.3	.24
C	.93	.75	65.4	24.5	12.0	13.5[b]	6.6	363.4[b]	1831.4	.26
D	1.10	.90	64.5	25.0	12.1	12.8[b]	6.2	345.5[b]	1860.1	.25
E	1.30	1.05	65.6	25.0	12.1	13.8[b]	6.7	378.6[b]	2031.1	.26
F	Trt B to 68 kg then D		65.9	23.7	11.9	12.7[b]	6.3	361.2[b]	1981.8	.25
G	Trt D to 68 kg then B		65.1	24.7	12.0	12.4[b]	6.0	332.0[b]	1792.3	.25
Standard Deviation[c]			±1.23	±1.74	±.18	±1.66	±.81	±57.3	±492.6	±.045

[ab]Means sharing a common superscript are not significantly different at (P<.10).

[c]Each value is the mean ± standard deviation of six boars.

TABLE 7. BONE DATA ON THE RIGHT ULNA FOR BOARS FED INDICATED LEVELS OF CALCIUM AND PHOSPHORUS

Treatment	Dietary Ca %	Dietary P %	Ash[d] %	Ca[d] %	P[d] %	Actual Ca[d] gms	Actual P[d] gms	Breaking Force[d] kg	Breaking Strength[d] kg/cm^2	Wall Thickness[d] cm
A	.55	.45	62.1	25.0	12.6	11.4	5.7	317.4[a]	1619.8	.23
B	.74	.60	64.9	25.8	13.0	12.3	6.2	363.5[ab]	1999.9	.23
C	.93	.75	64.7	25.0	13.2	13.9	7.4	402.3[bc]	1969.9	.24
D	1.10	.90	65.0	26.3	13.0	13.1	6.8	395.2[bc]	2271.5	.22
E	1.30	1.05	65.2	27.0	13.2	14.6	7.1	450.0[c]	2627.7	.24
F	Trt B to 68 kg then D		65.4	26.3	13.2	13.7	6.9	400.1[bc]	2018.6	.24
G	Trt D to 68 kg then B		64.4	25.5	13.0	13.1	6.7	358.6[ab]	1962.0	.24
Standard Deviation[d]			±2.02	±1.54	±.62	±2.04	±1.04	±56.5	±588.0	±.033

[abc]Means sharing a common superscript are not significantly different at (P<.05).

[d]Each value is the mean ± standard deviation of six boars.

TABLE 8. BONE DATA ON THE RIGHT RADIUS OF BOARS FED INDICATED LEVELS OF CALCIUM AND PHOSPHORUS

Treatment	Dietary Ca %	Dietary P %	Ash[d] %	Ca[d] %	P[d] %	Actual Ca[d] gms	Actual P[d] gms
A	.55	.45	65.6	26.6	13.1	8.4	4.1[ab]
B	.74	.60	65.5	26.9	12.4	9.1	4.2[ab]
C	.93	.75	64.4	27.6	13.8	10.0	4.8[c]
D	1.10	.90	65.8	27.0	12.5	8.5	3.9[a]
E	1.30	1.05	66.1	26.3	12.5	9.6	4.5[bc]
F	Trt B to 68 kg then D		66.5	25.7	12.5	9.1	4.4[abc]
G	Trt D to 68 kg then B		64.8	26.0	12.2	9.0	4.2[ab]
Standard Deviation[d]			±2.64	±2.51	±1.05	±.997	±.486

[abc]Means sharing a common superscript are not significantly different at (P<.10).

[d]Each value is the mean ± standard deviation of six boars.

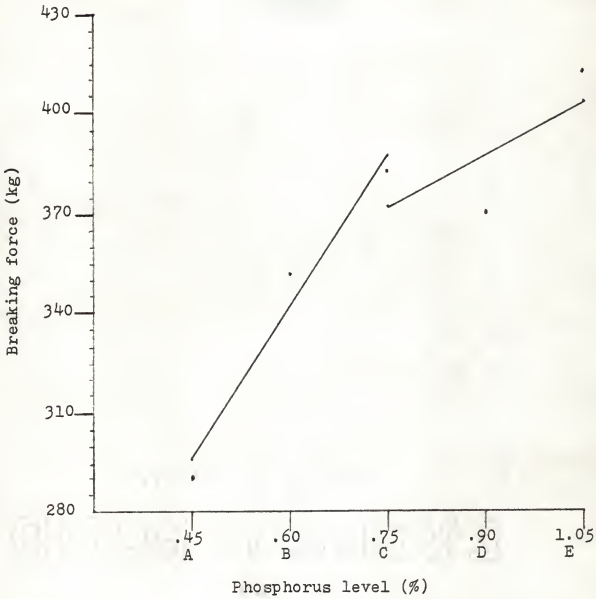

FIGURE 6. Linear regression of ulna breaking force on phosphorus level fed. Breaking force increased ($P<.05$) linearly in treatments A through C. The linear effect was not significant for treatments C through E.

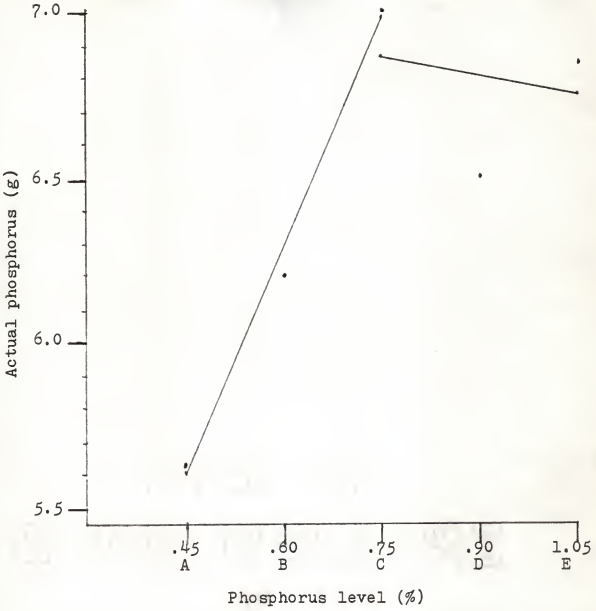

FIGURE 7. Linear regression of actual phosphorus content of the ulna (average of the left and right) on the level of phosphorus fed. Actual phosphorus content of the ulna increased ($P<.05$) linearly in treatments A through C. The linear effect was not significant for treatments C through E.

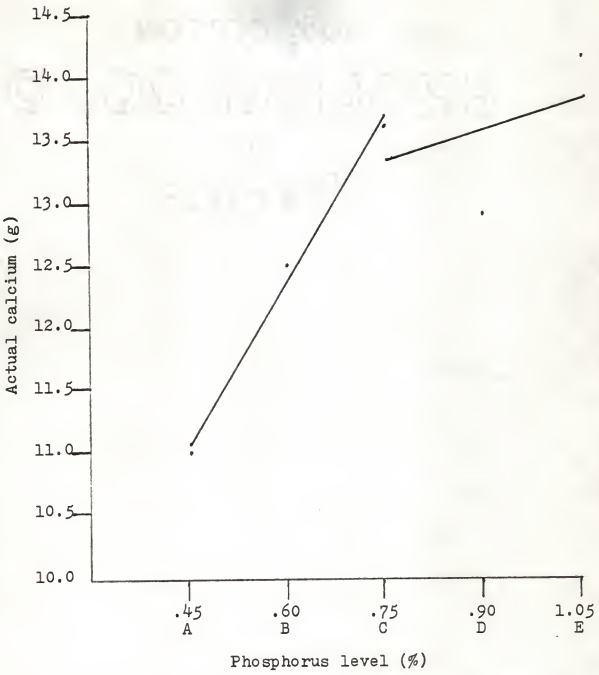

FIGURE 8. Linear regression of actual calcium content of the ulna (average of the left and right) on the level of phosphorus fed. Actual calcium content increased ($P<.05$) linearly in treatments A through C. The linear effect was not significant for treatments C through E.

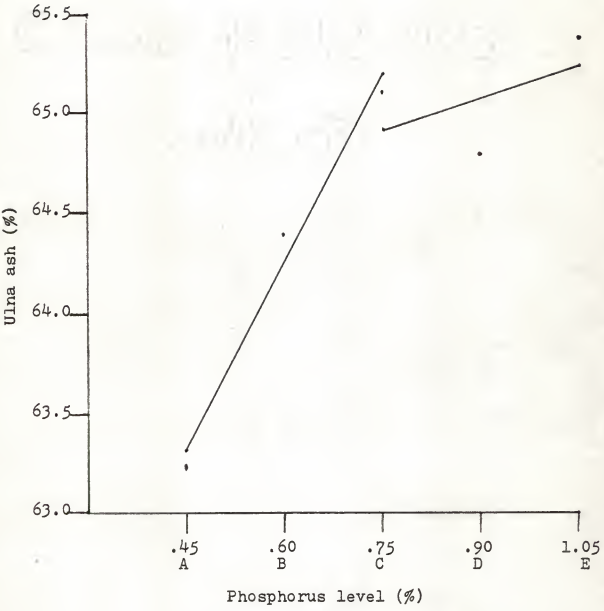

FIGURE 9. Linear regression of ulna ash % (average of left and right) on the phosphorus level fed. Ash increased ($P<.05$) linearly in treatments A through C. The linear effect was not significant in treatments C through E.

DISCUSSION

Average daily gain, average daily intake and feed efficiency were not significantly influenced above a level of 0.55% and 0.45%, dietary calcium and phosphorus, respectively. Cromwell et al. (1970) reported that feeding less than 0.50% dietary phosphorus resulted in significantly slower and less efficient gains for growing pigs. The National Research Council (1973) recommended the calcium and phosphorus requirements for growing and finishing swine as 0.50 and 0.40%, respectively. Pond et al, (1975) showed that the NRC recommended requirement for calcium and phosphorus was adequate for normal growth of growing and finishing swine. Libal et al. (1969) found that increasing the dietary phosphorus level from 0.30% to 0.70% linearly increased daily gain and feed intake in growing and finishing pigs. In contrast, Tanksley (1975) found that higher levels of dietary calcium and phosphorus reduced average daily gain, but feed intake and feed conversion were not significantly affected in growing and developing boars.

Apparently performance is altered when the phosphorus level is below the minimum requirement or when the ratio of Ca:P is high (over 2:1). Data from Chapman et al. (1962) and Zimmerman et al. (1963) suggests the calcium to phosphorus ratio becomes more critical when phosphorus is limiting in the diet.

Relatively high levels of dietary calcium and phosphorus were fed in this study (1.3% Ca, 1.05% P). Apparently, higher

Ca-P levels than recommended by NRC (1973) do not depress the growth rates of boars as long as the Ca:P ratio is maintained between 1.2:1 and 1.3:1. This observation is in agreement with data reported by Combs et al. (1960), Forsyth (1972), Cromwell (1972), Doige et al. (1975), Pond et al. (1975) and Reinhard et al. (1976).

Carcass characteristics were not altered significantly by the seven dietary treatments imposed. Cromwell et al. (1970) observed slightly shorter carcasses with significantly more backfat, smaller l. dorsi areas and a lower yield of ham and loin in growing-finishing pigs fed a level of dietary phosphorus less than recommended by NRC (1968). However, Cromwell et al. (1972) found that carcass traits were not significantly different among growing pigs fed from 0.50 to 0.95% dietary calcium and from 0.50 to 0.65% dietary phosphorus. No significant differences were found for finishing pigs when the dietary calcium level ranged from 0.35 to 0.80% and dietary phosphorus ranged from 0.40 to 0.50%.

Dietary calcium and phosphorus levels used in this study resulted in a linear increase in bone breaking force. However breaking strength (obtained by placing the bone breaking force on a constant bone area basis) was not significantly affected by dietary treatment. This suggests that there were no measurable differences in bone density among the dietary treatments. Tanksley (1975) reported a significant linear effect of calcium and phosphorus on femur weight, sidewall thickness and sidewall area of femurs in boars fed calcium and phosphorus

levels ranging from 0.50, 0.50% to 1.2, 1.0% calcium and phosphorus, respectively. He suggested that the higher breaking loads obtained in his study could be in part due to the increase in these parameters since breaking strength (expressed in kg/cm^2) was not significantly affected by dietary treatment. Thus his data suggests no appreciable effect of calcium and phosphorus on bone density of growing and developing boars.

In contrast, the wall thickness of bones studied in this experiment were not significantly influenced by dietary calcium and/or phosphorus. Apparently the lowest level of dietary calcium and phosphorus used in this study (0.55% Ca, 0.45% P) was adequate for providing normal wall thickness of the ulna in growing and developing boars. A significant positive correlation (r=.34) was observed between breaking force and wall thickness indicating a positive relationship between these two criteria. Cromwell et al. (1972) suggested that 0.80% calcium with a level of either 0.50 or 0.65% phosphorus maximized breaking strength in bones taken from growing and finishing pigs. They attributed this increase in strength to an increase in thickness of the bone since metacarpal breaking strength was positively correlated with metacarpal weight (r=0.64, P<.01) and thickness (r=0.28, P<.05), but not significantly correlated with length (r=0.02) or outside diameter (r=0.14). Thus, the increase in breaking force observed in the present study could be due to a small increase in wall thickness even though this parameter was not significantly different.

The percent ash, Ca and P of the radius and ulna did not increase as the dietary calcium and phosphorus level increased

from 0.55 to 1.3%, 0.45 to 1.05% calcium and phosphorus, respectively. These results are in agreement with those of Fammatre et al. (1977). They found no apparent influence of calcium and phosphorus levels on percent ash in bones taken from finishing pigs. Harmon et al. (1970) also reported that the percent ash, calcium and phosphorus of ribs taken from 90 kg pigs was not increased when the total dietary phosphorus level was greater than 0.50%, with a Ca:P ratio of 1.6:1. Cromwell et al. (1972), Peo et al. (1967), Johnson et al. (1962) Futrell et al. (1969), Stockland and Blaylock (1973) reported similar results in finishing pigs. Several workers have reported a positive response to added dietary phosphorus on percentage of ash content in bones taken from finishing pigs. (These include data reported by: Combs et al. (1960), Cromwell et al. (1970), Combs et al. (1962), Bayley et al. (1975).) These studies reported an increase in percent bone ash as the dietary phosphorus increased, but the response plateaued at a level of 0.55% total dietary phosphorus. This suggests that bone ash may be affected by increasing dietary phosphorus levels starting somewhere below 0.55% total dietary phosphorus. In contrast, Pond et al. (1975) reported that the ash content of the radius and ulna tended to be higher from pigs fed 1.2% Ca, 1% P than that of the radius and ulna from pigs fed 0.50% Ca, 0.40% P. Tanksley (1975) reported similar results in boars fed higher levels of dietary calcium and phosphorus.

The ratio of Ca:P in the radius and ulna is close to 2:1 for every treatment group. Blair et al. (1963) also found a

ratio of 2:1 in bones taken from 20 kg pigs. Nielsen (1972) reported that the calcium:phosphorus ratio in bone was very uniform and varied from 2.0 to 2.2. Brown et al. (1972) reported that the Ca:P ratio in the radius and ulna changed with age. The calcium:phosphorus ratio of the lower segment of the ulna varied from 1.51, 2.55, 2.14, 1.67 to 1.62 for 4, 8, 12, 16 and 24 week old pigs, respectively. The head segment of the ulna ranged from 1.64, 2.61, 2.13, 1.68 to 1.62 for 4, 8, 12, 16 and 24 week old pigs, respectively. The radius followed a similar pattern in change regarding the Ca:P ratio with age.

The ash, calcium and phosphorus content of the radius and ulna are higher than the results of other studies. This might be attributed to the removal of the bone marrow before analysis.

The force required to break the ulnas (breaking force) was significantly greater for treatments containing 0.74 through 1.3% dietary calcium and 0.60 through 1.05% dietary phosphorus than for the lowest treatment level fed (0.55% Ca, 0.45% P). Also, boars fed a level of 0.74% Ca and 0.60% dietary phosphorus from 29 kg to 68 kg followed by 1.10, 0.90% (dietary calcium and phosphorus, respectively) from 68 kg to 118 kg possessed bones with a significantly higher breaking force than boars fed the lowest treatment level (0.55% Ca, 0.45% P). These results suggest that boars require a higher level of dietary Ca and P during the period of growth from 68 to 118 kg than from 29 to 68 kg to maximize bone strength.

Newman and Elliot (1976), demonstrated that both the source and level of dietary phosphorus influenced the performance of

growing swine from 16 to 46 kg, but not during the finishing period. Reinhard et al. (1976) suggested that the optimum time to assess mineral requirements for bone development is during or immediately following the growth phase. Fammatre et al. (1977) also suggested that the level of dietary calcium and phosphorus during the finishing phase is not as critical for bone development as during the growing period. Apparently, the mineral requirement for rapidly growing and developing boars differ not only in terms of amounts, but also in terms of period of growth, since in boars used in this study, maximum bone strength occurred when higher levels of Ca and P were fed during what would be considered the finishing phase for growing and finishing pigs. It appears that a level of 0.55, 0.45% dietary calcium and phosphorus, respectively, is adequate for growth and normal carcass traits in rapidly growing boars, from 29 to 118 kg. However, for maximum bone development in boars, a level of 0.74, 0.60% dietary calcium and phosphorus, respectively, is required. Tanksley (1975) found a similar requirement for phosphorus (0.75%), but a slightly lower requirement for calcium (0.75%) when metacarpal breaking load was used as an indicator of bone strength. Bayley et al. (1975) reported a lower requirement for phosphorus (0.60%) on growth and bone development in boars.

SUMMARY

Forty-two crossbred boars averaging 29 kg were randomly assigned to seven dietary treatments after being allotted by weight and litter. Calcium to phosphorus ratio of 1.2:1 was maintained in all diets. Phosphorus levels studied ranged from a low of 0.45 to a high of 1.05%. The basal corn-soybean meal diet supplied 0.32% phosphorus. Seven treatment groups were replicated three times. Two of the seven were a combination of two dietary levels of phosphorus. One group was fed 0.60% P from 30 to 68 kg followed by 0.90% P from 68 to 118 kg. The other group was fed 0.90% P from 30 to 68 kg followed by 0.60% P from 68 to 118 kg. Boars were slaughtered at an average weight of 118 kg at which time both front legs were removed from each boar to determine the effect of P level on bone strength, bone ash, bone Ca and P content. There were no significant effects of P level on weight gain, feed utilization, feed intake, carcass length or backfat.

Ulna bone breaking force increased ($P<.05$) linearly with increasing P levels. Linear regression of breaking force (ave. L and R ulna) on phosphorus level was significant ($P<.05$) for treatments 0.45 through 0.75% phosphorus. However, linear effects were not significant for treatments 0.75 through 1.05% phosphorus. Breaking strength (expressed in kg/cm^2) increased linearly ($P<.05$) with increasing levels of phosphorus. The highest breaking strength occurred at the highest level of phosphorus.

The actual calcium and actual phosphorus (obtained by multiplying the dry fat free sample by the % obtained in the ash) of the ulna increased ($P<.05$) linearly in treatments from .45 through .75% dietary phosphorus. The linear effect in treatments .75 through 1.05 was not significant. Several parameters (actual calcium, actual phosphorus, breaking force, wall thickness and ash) indicated that bone development is near maximization at 0.93, 0.75% dietary Ca and P.

Boars fed 0.60% P from 30 to 68 kg, followed by 0.90% P from 68 to 118 kg possessed bone development similar to boars fed 0.75% P the length of the trial. This suggests that boars need higher levels of P during the stage of growth from 68 to 118 kg.

Results of this study suggest that dietary levels of 0.55% Ca, 0.45% P are adequate for: weight gain, feed utilization, feed intake, carcass length and backfat. However, for maximum bone development, a level of at least 0.93% Ca, 0.75% P should be supplied in the diets of growing boars from 29 to 118 kg live weight.

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CALCIUM AND PHOSPHORUS REQUIREMENTS FOR DEVELOPING BOARS

by

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

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MASTER OF SCIENCE

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Forty-two crossbred boars averaging 29 kg were randomly assigned to seven dietary treatments after being allotted by weight and litter. Calcium to phosphorus ratio of 1.2:1 was maintained in all diets. Phosphorus levels studied ranged from a low of 0.45 to a high of 1.05%. The basal corn-soybean meal diet supplied 0.32% phosphorus. Seven treatment groups were replicated three times. Two of the seven were a combination of two dietary levels of phosphorus. One group was fed 0.60% P from 30 to 68 kg followed by 0.90% P from 68 to 118 kg. The other group was fed 0.90% P from 30 to 68 kg followed by 0.60% P from 68 to 118 kg. Boars were slaughtered at an average weight of 118 kg at which time both front legs were removed from each boar to determine the effect of P level on bone strength, bone ash, bone Ca and P content. There were no significant effects of P level on weight gain, feed utilization, feed intake, carcass length or backfat.

Ulna bone breaking force increased ($P<.05$) linearly with increasing P levels. Linear regression of breaking force (average left and right ulna) on phosphorus level was significant ($P<.05$) for treatments 0.45 through 0.75% phosphorus. However, linear effects were not significant for treatments 0.75 through 1.05% phosphorus. Breaking strength (expressed in kg/cm^2) increased linearly ($P<.05$) with increasing levels of phosphorus. The highest breaking strength occurred at the highest level of phosphorus.

The actual calcium and actual phosphorus (obtained by multiplying the dry fat free sample by the % obtained in the

ash) of the ulna increased ($P<.05$) linearly in treatments from 0.45 through 0.75% dietary phosphorus. The linear effect in treatments 0.75 through 1.05 was not significant. Several parameters (actual calcium, actual phosphorus, breaking force, wall thickness and ash) indicated that bone development is near maximization at 0.93, 0.75% dietary Ca and P.

Boars fed 0.60% P from 30 to 68 kg, followed by 0.90% P from 68 to 118 kg possessed bone development similar to boars fed 0.75% P the length of the trial. This suggests that boars need higher levels of P during the stage of growth from 68 to 118 kg.

Results of this study suggest that dietary levels of 0.55% Ca, 0.45% P are adequate for: weight gain, feed utilization, feed intake, carcass length and backfat. However, for maximum bone development, a level of at least 0.93% Ca, 0.75% P should be supplied in the diets of growing boars from 29 to 118 kg live weight.